PIONEERS IN CONCRETE BRIDGES

Nebraska bridges evolve from 1900s to 2000s...and beyond

by Fouad Jaber, Nebraska Department of Roads

Nebraska is not a stranger to concrete bridges. State inventory figures reveal that there are approximately 5000 cast-in-place concrete (mostly slab) bridges and 1500 precast, prestressed concrete girder bridges. A look at some of these bridges demonstrates how rapidly Nebraska's bridge technology has evolved over the years and why the state is among the pioneers in concrete bridge technology.

The earliest concrete bridges in Nebraska date to the early 1900s; these modest concrete bridges, including concrete arch and box culverts, appear throughout the state. By the second decade of the twentieth century, concrete gained favor as a material for a bridge's superstructure. Concrete plans were standardized and concrete slab bridges and concrete arch bridges became increasingly common into the 1920s and beyond.

In 1911, state legislation created the State Aid Bridge Fund, which led to increased funding and building of bridges. A shortage of funds during the Depression forced Nebraska to phase out the popular program, with the last appropriation occurring in 1933.

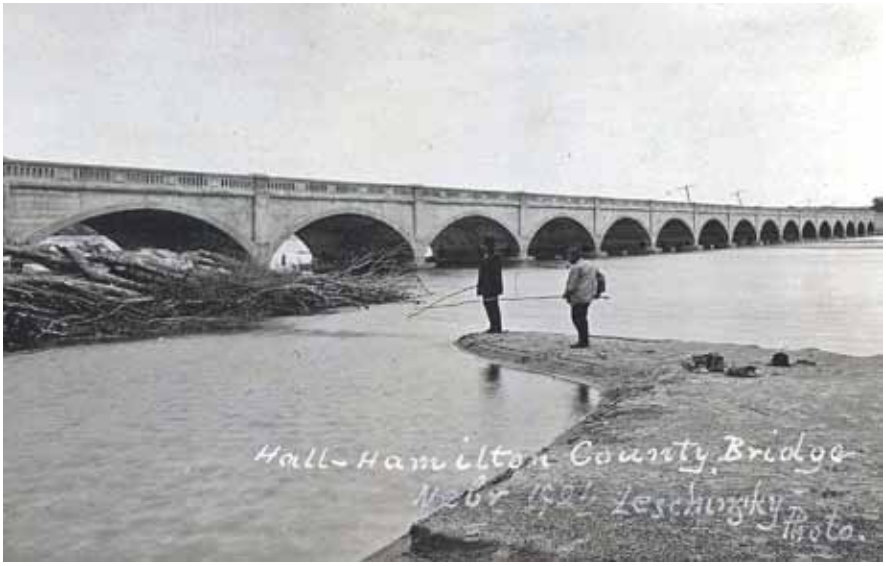
During the fund's existence, a total of 97 bridges at 80 locations were built or purchased. These bridges included designs popular during the period, including steel trusses, stringers and transverse-joist girders, concrete arches, and girders. A surprising number of well-preserved concrete bridges survive from this period.

Jointless Bridges Emerge

In the 1930s and 1940s, concrete bridges continued to become more economically feasible and increased in number. In the 1950s, Nebraska was among the first to build precast, prestressed concrete bridges, with four of these bridges located along the Sherman Reservoir in central Nebraska. These were simple-span girder designs without diaphragms at the interior supports. This design evolved in the following decades to simple span for dead load and continuous for live load by adding diaphragms at the interior supports starting in the 1970s. Thus, the concept of "jointless bridges" was born.

The jointless bridge system eliminates all expansion joints over the entire length of the bridge superstructure, and limits joints to locations at the junction between the bridge approach slab and the pavement. With this system, the opportunity for joint leakage over the abutments and pier bearing areas is eliminated. This is not only an important durability issue, but also a very significant aesthetic issue. Having expansion or separation joints through the deck over the supports creates the potential for stains, cracking due to freezing and thawing, and spalling.

Performance of bridges designed using the Nebraska system have stood the test of time. A number of structurally sound, 40-year-old bridges are being replaced due to Interstate realignment. The girders being removed appear to be as good as new, despite Nebraska's harsh weather and use of deicing salts. This validates the Nebraska Department of Roads' (NDOR's) design philosophy, which results in significant savings in prestressing levels and better control of cambers.



The photo shows the historic Hall-Hamilton County Bridge in 1926. All photos: Nebraska Department of Roads.

University Influence

Nebraska is the birthplace of the NU (Nebraska University) hard SI I-girder series, developed in 1992. The NU girder series, NU900 to NU2000, vary in depth from 900 to 2000 mm (36 to 79 in.). These new shapes, despite the national retreat from the SI system, proved to have significant advantages compared to the previously used AASHTO girders. They:

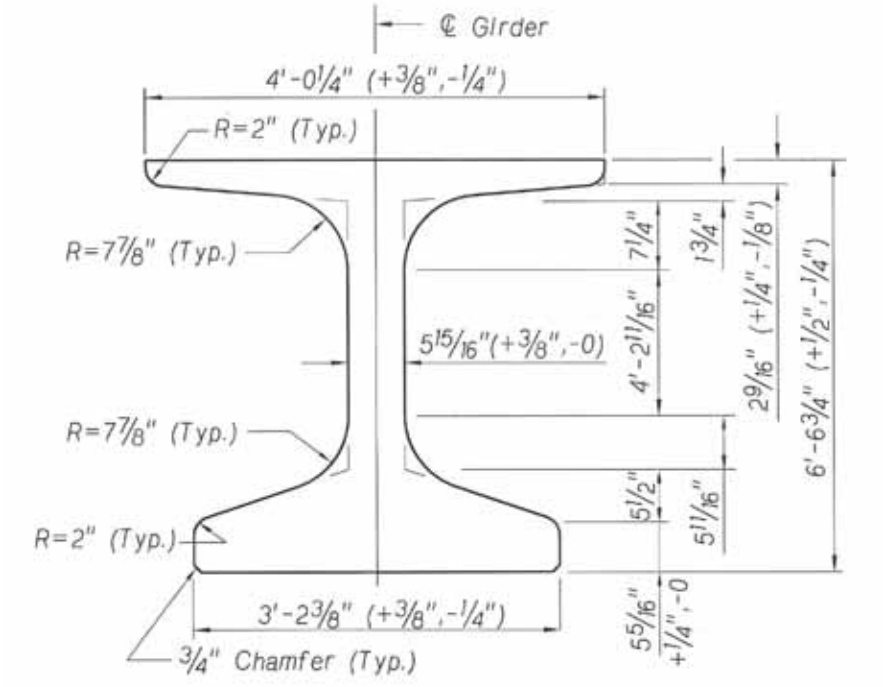
- are more stable during handling and erection,
- house more strands, resulting in longer span capacities for the same depth, and
- take advantage of the improvements in concrete technology such as high-strength, self-consolidating concrete that allows for thin, cross-section geometry.

This new series of girders was selected as the standard girder I-shape by NDOR, providing a clear direction for consultants, suppliers, and contractors. The ability of the 38-in.-wide bottom flange to hold up to sixty 0.6-in.-diameter strands creates the potential for a relatively shallow structural depth. A 5.9-in.-thick web allows ample shear capacity while keeping the girder weight to a minimum. A 48-in.-wide thin top flange reduces the cost of deck forming, improves buckling stability, and minimizes the girder weight.

Since its introduction, the NU girder series has been exclusively used in Nebraska for spans up to 206 ft. The 204th Street Skyline Bridge in Omaha, completed in 2004, was the first bridge to achieve this span length. It used NU2000 79-in.-deep girders at 9 ft spacing.

This highly efficient design was possible through the use of a combination of pretensioning and post-tensioning of three segments with lengths of 28, 150, and 28 ft. The prestressing consisted of 46 pretensioning strands and 45 post-tensioning strands. Self-consolidating, 10,000 psi compressive strength concrete was used for the girders.

The bridge's main 206-ft-long span featured three girder segments per girder line with two cast-in-place concrete splice joints. This is thought to be the longest simple span with the greatest girder span-to-depth ratio of any bridge



This drawing shows the typical dimensions of a NU2000 girder.

in the country. The bridge is a strong example extending the adaptability of precast, prestressed concrete girders to longer spans to compete with other materials.

A number of bridge overpasses were constructed between Omaha and Lincoln in the past 15 years as part of the I-80 widening to three lanes in each direction. The I-80 widening effort required the replacement of many older, four-span steel and concrete structures. The replacement bridges were typically two-span concrete structures, which were selected to take advantage of performance characteristics that allow the superstructure depth to essentially remain unchanged. This reduced the number of issues related to meeting existing business access and road crossing grades. Most of these bridges are precast, prestressed concrete structures with span-to-depth ratios near 30. These bridges are often mistaken for slab bridges because of their shallow depth and elegant appearance.

Teamwork

The state of Nebraska prides itself in creating effective partnerships. The team environment established with the Federal Highway Administration; the NDOR; the University of Nebraska (UNL); the precast concrete suppliers, represented by the Prestressed Concrete Association of Nebraska (PCAN); and the contractors, represented by the Associated General Contractors of Nebraska has been extremely beneficial. In the past several decades, much of the innovation and progress in Nebraska is directly attributed to this partnership. The introduction of the NU I-girder is one of the early examples.

Other innovations include the use of high-strength concrete and self-consolidating concrete (SCC) in all bridge girders, which has been a standard practice in the state for all precast, prestressed concrete bridge products since the early 2000s. SCC was used in the Dodge Street Bridge in Omaha.

Nebraska was the selected site for the first high-performance concrete demonstration bridge project. Opened to traffic in 1997, the 120th Street and Giles Avenue Bridge, in Sarpy County, incorporated 12,000 psi precast, prestressed concrete girders and an 8000 psi cast-in-place concrete deck, and is another example of successful teamwork.

Dodge Street Bridge is an example of an elevated highway bridge in Omaha, Neb.

Innovation Continues

Another recently introduced innovation pioneered by Nebraska is the use of 0.7-in.-diameter strands. This strand size is available in the United States but had been limited to the mining industry and cable-stayed bridge applications. The 0.7-in.-diameter size has a cross-sectional area of 0.294 in.^{2} and thus allows for nearly twice the prestressing force over that provided by 0.5-in.-diameter strands.

The Pacific Street Bridge over I-680 in Omaha was completed in 2008 and was the culmination of ongoing research on the impact of using 0.7-in.-diameter strands in NU I-girders; it was the first bridge in the United States to utilize this unique strand size. A standard high-performance concrete design was used to deliver the specified concrete compressive strengths of 10,000 psi. Indications are that labor savings, combined with the ability to introduce almost twice the prestressing force, will lead to a significant future increase in the span capability of the current NDOR NU I-girder, without having to modify the sections or acquire new forms.

A typical NU girder bridge overpass over I-80.

Nebraska continues to refine and advance NU I-girder design and construction. Recent developments include use of high-strength rods to create continuity for deck weight and the creation of a new, cost-effective, 15,000 psi compressive strength precast concrete mixture.

The Grand Island Bridge over I-80, built in 2003, was the first bridge designed continuous for dead load and live load and is a prime example of the use of threaded rod continuity over the pier. This structure has two 145-ft-long spans using NU1100 girders. This innovative solution allowed bridge girders to be extended in their span range.

The Arbor Road Bridge put into use another innovative system. The structure is the first for Nebraska, and one of the first in the United States, utilizing precast concrete curved girders. The curved girders, which are approximately 4 ft tall, spanned about 140 ft over the Interstate near Lincoln, Neb. The tub-shaped girders consist of straight 40-ft-long segments that are kinked at the joints. Commuters on the interstate cannot tell if the bridge girders are truly curved or just made of chorded 40 ft straight lines.

Creative Deck Design

Nebraska has developed an innovative full-depth, full-width precast concrete deck system (NUDECK 1st Generation). The panels were first used on a bridge in the Skyline development, near the 204th Street Skyline Bridge. The system, developed in collaboration with UNL and PCAN, extends service life and accelerates bridge construction.

The precast, transversely pretensioned, longitudinally post-tensioned concrete panels, ensure a crack-free, two-way prestressed concrete deck system. This innovative deck system was designed for long-term durability and low maintenance requirements. Currently Nebraska engineers are in the process of designing the 2nd generation NUDECK scheduled to be constructed in 2013.

During the past decade, the trend toward longer, stronger and lighter concrete bridges has continued. Shortly, Nebraska will combine, for the first time, 15,000 psi compressive strength concrete girders, with 0.7-in.-diameter strands, and threaded rod continuity, in a single application.

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For more information about Nebraska's bridges visit www.roads.ne.gov/design/bridge/

Grand Island Bridge over I-80 utilizes threaded 150 ksi reinforcing-bar connections for full continuity of dead load and live load over the support.

Arbor Road Bridge over I-80 in Lincoln, Neb., used curved precast concrete box girders.

NUDECK being installed over the Skyline Bridge near Omaha, Neb.